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REPORT OF STEAM RELEASE EVENT EXTRACTION WELL EW-5 VISALIA STEAM REMEDIATION PROJECT

Prepared By:

Southern California Edison
Environmental Affairs Department

April 30, 1999

Signature:

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May 4, 1999

Mr. Emmanuel Mensah
Waste Management Engineer
California Environmental
Protection Agency
Department of Toxic Substances Control
10151 Croydon Way, Suite 3
Sacramento, Ca 95827

Subject: Visalia Pole Yard
Visalia Steam Remediation Project / Steam Release Event

Dear Mr. Mensah:

As we have discussed, I am enclosing two copies of a report on the steam release event that occurred on February 1, 1999. This report is also being distributed to other individuals as indicated on the list below.

If you have any questions, I can be reached at (626) 302-2216.

Sincerely,

GM Becker

George M. Becker
Senior Environmental Specialist

cc:
Mr. Dick Procunier, USEPA, Region IX (1)
Mr. Joel Martens, Tulare County Env. Health (2)
Dr. Eva Davis, USEPA, RSKERC-Ada, Ok.(1)
Mr. Britt Fussel, City of Visalia (2)

STEAM RELEASE EVENT
EXTRACTION WELL EW-5
VISALIA STEAM REMEDIATION PROJECT

INTRODUCTION

Southern California Edison Company (SCE) is currently conducting a steam remediation project at the Visalia Pole Yard to remove pole-treating chemicals from the subsurface. On the morning of February 1st, 1999, a steam rupture occurred in a ground water extraction well at the site. The steam, which was being injected into the subsurface at a depth of 125 feet, vented to the surface through an annular seal between the well casing and conductor casing of well EW-5. The steam release continued unabated until approximately 8:30 PM that evening. The location of well EW-5 is shown on the attached Site Plan figure.

During the release, both steam vapor and sediments from the subsurface were ejected. Sediments were deposited on the ground surface in a generally radial pattern from the well. They consisted primarily of silts and fine sands from the subsurface area immediately adjacent to the well borehole. The majority of the material was deposited on the Pole Yard property and the adjacent City of Visalia General Services Yard, located to the south.

During the initial period of the release, Ben Maddox Way was temporarily closed, until the safety of passing motorists could be assured. Personnel from Tulare County Environmental Health responded to the scene to assist in evaluating whether any health hazards were present. Later in the day, an Edison Project Manager and our steam remediation consultant from Lawrence Livermore National Laboratory (LLNL) arrived at the site to manage the situation. A preliminary analysis of the failure was conducted by LLNL and is attached in Appendix A.

SCE conducted airborne health hazard monitoring during the event, and follow-up studies of the ejected material. All monitoring and follow-up health risk evaluations determined there were no health risks associated with the subject release. This conclusion was independently verified by the California EPA, Department of Toxic Substances Control.

The material deposited in the City Yard was subsequently removed and returned to the Pole Yard property. The ruptured well was permanently sealed, and all other on-site and off-site wells with similar construction were modified to prevent a similar occurrence.

CAUSE OF RELEASE

The steam release was caused by the failure of a bentonite seal, originally placed between the well and conductor casings during construction. Steam under a pressure of approximately 40 pounds per square inch (psi) is thought to have first eroded the bentonite borehole seal in the uppermost part of the deeper aquifer. It made its way upward into the annular space between the casings at a depth of approximately 107 feet, where the bottom of the conductor casing is located. From there the steam continued to erode the seal material until it reached the surface. A diagram of the well construction and steam release pathway is shown in the Steam Release Pathway figure. At the surface, the steam developed enough lifting force to break the concrete well slab, and vent to the atmosphere.

CLEANUP ACTIVITIES

Prior to cleanup activities, the ejected material was determined to be non-hazardous by analytical testing and characterization (discussed later). The material was removed from the City Yard and transported to the soil treatment unit on the Pole Yard property. Clean-up activities were initiated on February 2nd and completed on February 5th.

HEALTH RISK ASSESSMENT

Air Monitoring

Within approximately one hour of the initial steam release, air monitoring was initiated on a 20-minute interval, utilizing a RAE Systems, Model PGM 761S, photo-ionization detector. This monitoring interval was maintained between 10:30 AM and 1:50 PM. During that time frame, there were no significant measurable volatile emissions. Instrument response varied between 0.0 and 0.1 parts per million (ppm). The Visalia Steam Remediation Project Health and Safety Plan designates 5 ppm volatile emissions as an action level. Monitoring data and sampling locations are shown in the figures included in Appendix B.

Ejected Soil Analysis

In order to evaluate potential health risks associated with the ejected sediments, samples were obtained from both the Pole Yard property and City Yard. These samples were collected mid-day on February 1st and transported to Calscience Environmental Laboratories, in Garden Grove, California, for immediate analysis of the chemicals of concern. Laboratory analysis was completed late that night, and a regulatory analysis of the findings was conducted through the night and into the following morning. A copy of the laboratory reports and a figure showing sample locations are included in Appendix C.

Waste Characterization And Health Risk Assessment

The analytical results for the city yard site sample and the VPY site sample were compared to regulatory concentrations. No sample value exceeded the *Maximum Concentration for the Toxicity Characteristic* published in 22 CCR 66261.24. It was also determined that none of the analytical results exceeded *EPA's Preliminary Remediation Goals* for Industrial sites.

Additional research determined that the oral LD_{50} for Phenanthrene (700ppm) was less than 5,000ppm (Merck Index, Tenth Edition). The mixture containing Phenanthrene was determined to be non-hazardous by using the formula published in 22 CCR 66261.24[c] .

Once the material was determined to be non-hazardous , another determination was made as to whether the pole-treating chemicals found in the sediments posed a health risk to either the Pole Yard and City Yard workers, or to the cleanup crews. The sediment concentrations were compared to the acceptable site-specific exposure concentrations developed during the Remedial Investigation/Feasibility Study phases of site characterization (please refer to section 3 of the Feasibility Report, Southern California Edison Visalia Pole Yard, Visalia, California, dated September 1992, for specific information). These included both carcinogenic and non-carcinogenic polyaromatic hydrocarbons (PAH's). The average carcinogenic PAH concentration in the sediments was 4 mg/Kg (with an exposure duration of 5 days). The site-specific acceptable occupational concentration for these compounds is 78 mg/Kg (assuming 450 days of exposure). The average non-carcinogenic PAH concentration was 22.2 mg/Kg, as compared to the site-specific acceptable concentration of 460,000 mg/Kg.

DTSC Health Risk Analysis

The California EPA Department of Toxic Substances Control (DTSC) conducted an independent evaluation of the potential health risks to exposed workers, using the most current US EPA *Preliminary Remediation Goals.* DTSC also determined there was no adverse health risk posed by the release. A copy of their findings is included in Appendix D.

WELL MODIFICATIONS

EW-5

After steam ceased venting, geophysical logging was conducted in well EW-5 to determine where subsurface voids may have been created by the release. The logging indicated a void had been created between the depths of about 90 and 125 feet below grade. Based on these findings, Edison decided to abandon the well. Abandonment consisted of backfilling the well screen (between 128 and 178 feet below grade) with sand, and pressure-grouting the remainder of the well and adjacent void area. On February 3rd, the well and conductor casing were perforated and pressure-grouted by Halliburton Energy Services. Approximately 24 cubic yards of high-temperature cement was introduced into the subsurface through a special wellhead designed to prevent the release of residual steam, if present, when the conductor casing was perforated.

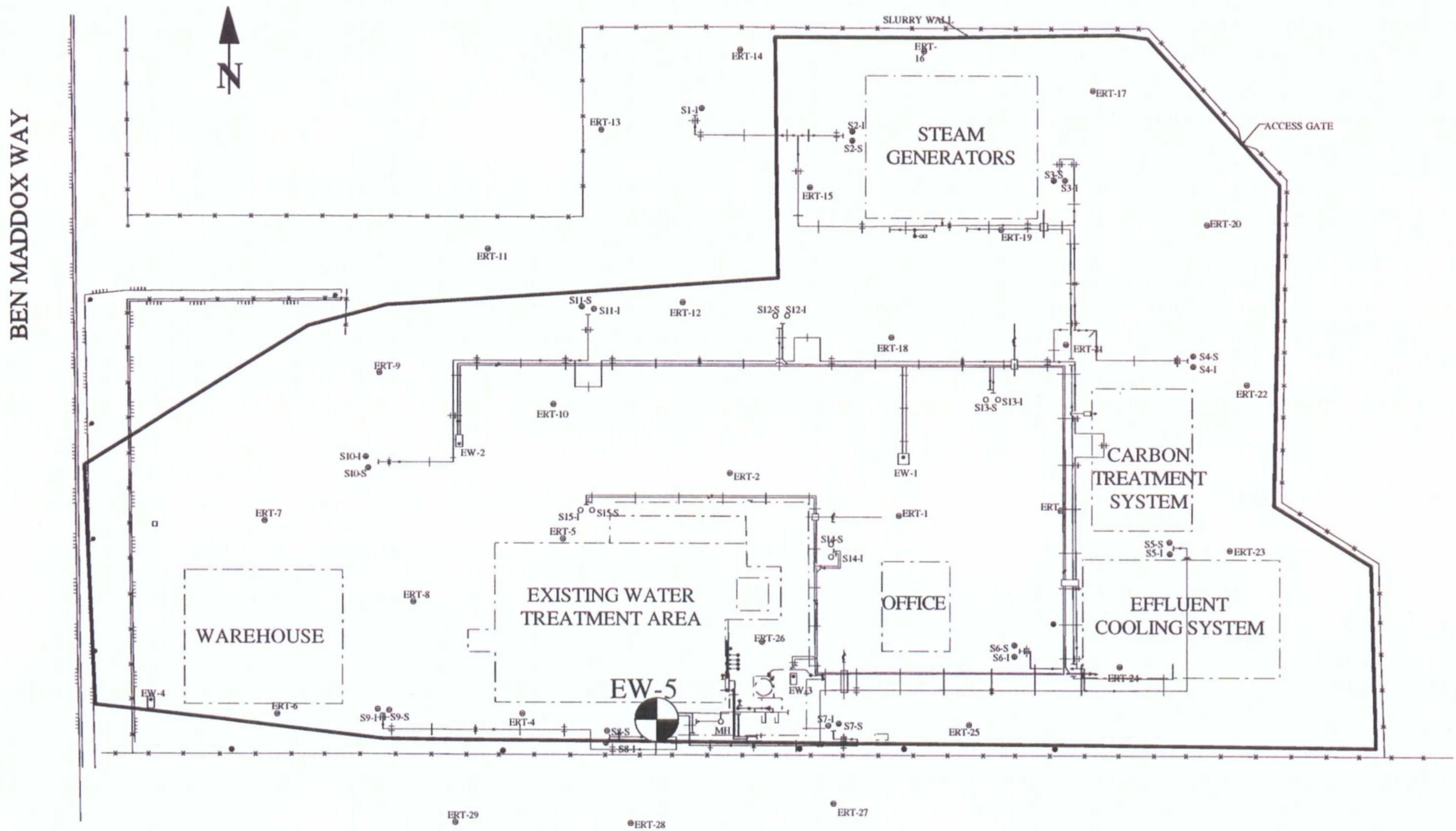
Other Well Modifications

There are a number of monitoring and extraction wells on the site with similar construction to well EW-5. In order to prevent a similar occurrence, Edison conducted an engineering analysis of these wells to develop modifications to prevent another release. Conceptually, the simplest and most expedient modification was to: 1) weld a steel plate over each of the annular spaces, sealing them off and connecting the well casing to the cemented conductor, or; 2) welding a steel plate over the entire conductor. This modification removes conduits to the surface, and ties the well and conductor casings together. In this configuration, the lifting force created by formation pressure would have to lift the entire well out of the ground in order for steam to escape to the surface. To evaluate the adequacy of this modification, an analysis of the well weight versus lifting force was performed. For the analysis, a very conservative 100 psi formation pressure from steam injection was used to calculate lifting force on each well configuration. This formation pressure is 2.5 times the 40 psi calculated from the February event. Dead weight of each well configuration was then compared to the calculated lifting force. Friction forces of the soil against the outer cement seal were neglected for further conservatism. The minimum factor of safety in each case was 1.5.

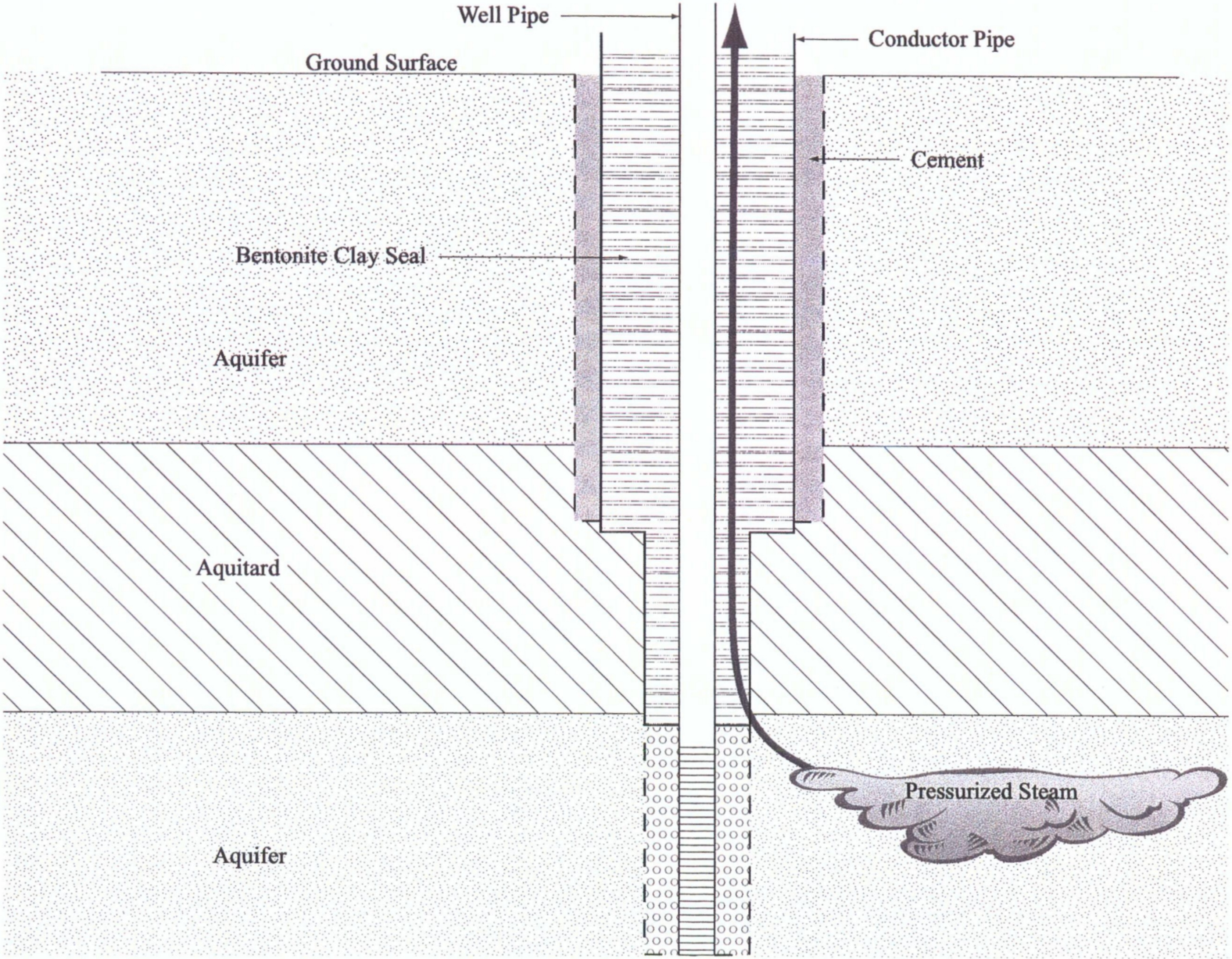
CONCLUSIONS

There were no injuries or significant damage associated with the steam release. The ejected material has been determined to be non-hazardous and did not present a health threat to workers or the public. Extraction well EW-5 was abandoned and all wells with similar construction were modified to prevent a similar occurrence.

FIGURES



SITE PLAN
EW-5 EVENT
VISALIA POLE YARD



STEAM RELEASE PATHWAY
EW-5 EVENT
VISALIA POLE YARD

APPENDIX A

Preliminary analysis of the failure of well EW-5, Visalia Pole Yard, February 1, 1999

Roger Aines and Robin Newmark
Lawrence Livermore National Laboratory

Events

EW-5 Steam Venting On February 1 at about 9:30 a.m., operators (John Dyda's account) heard a loud roaring sound coming from the vicinity of the treatment plant. Through a heavy fog, they could see a large column of steam erupting out of well EW-5. The sound of the eruption varied throughout the day, indicating changes in flow rate or path. Occasional louder bursts were heard as well. In the afternoon the intensity of the sound diminished. Photographs from the afternoon show a steam plume reaching at least 100 ft into the air.

Steam injection into S 14D and S 9D, which had been ongoing at about 15,000 lb/hr each, was halted immediately. Extraction from S 9D continued, while EW 5 extraction was halted. The vacuum system was shut down due to the need to burn the extracted vapor in the boiler, which had to be shut down since there was no place to safely inject the steam produced. Attempts to quench the eruption with water, according to SCE procedure, failed due to the massive amount of steam coming out of the hole. At about 6:30 p.m. operators began flooding well S-14D with cold water at a rate of about 100 gpm. This well is approximately 75 ft NE of well EW-5 and is completed in the same aquifer.

Eruption ceased suddenly at about 8:30 p.m.; this was attributed to the bridging of formation material in the open conduit. Once the eruption stopped, the well could be approached. At 9:30 p.m., quench water, at a rate of approximately 40 gpm, was introduced through a hole in the 8" well casing; this hole was a remnant of the original quench port, which had broken off during the eruption.

Observation at 8:00 p.m., after eruption stopped, showed that the eruption had come from the 16" steel telescoping casing that had been used to protect the deep well from the introduction of near-surface contamination during drilling. This casing ends at 107 ft depth, according to construction logs. A plumb weight was used to tag the casing, showing a hard obstruction at 31 ft depth at that time. At 9:30 p.m. the 16" casing was completely empty, and clean, bubbling water could be seen within it at about 40 to 50 ft depth. After one hour of injecting quench water into the 8" casing, the water in the 16" casing was no longer bubbling and was crystal clear. The bottom of the water could not be seen. The next morning, Craig Eaker tagged the bottom of the water zone (which is, presumably, the top of the bridge) at 91.8 ft bgs.

SCE personnel appeared to follow all applicable safety procedures. There were no injuries from this event.

Ejecta Analysis Throughout the day of February 1, sand and silt rained out of the steam plume. Near the wellhead, streaks of brown could be seen in the steam as it rushed upward. The majority of observed ejecta fell in a quadrant approximately centered due east of the well, so that about half of the material fell on the Visalia City Yard property (Figure 1 is a map of the Pole Yard and well locations). On February 2, the depth of this material was measured radially away from the EW-5 well, approximately in an easterly direction in the City yard. Observed depths were:

4"	to approx. 30 ft
2"	to approx. 50 ft
1"	to approx. 70 ft
1/2"	to approx. 100 ft
1/4"	to approx. 200 ft

A substantial amount of sand was observed to the eastern edge of the SCE property, sufficient to coat horizontal surfaces and impart a uniform tan color to objects.

Depths were uneven, and considerable washing of the fallout had apparently occurred, demonstrated by the presence of some channels, winnowing, and surface coverings of coarse sand underlain by more silt-rich material. The fallout pattern was assumed to be approximately radial, covering a section of 1/3 of a circle around the well, centered eastward. The above depths indicated a total amount of material between 20 and 50 cubic yards. Cleanup crews later removed 15 cubic yards of material from the city yard, validating this estimate assuming that one half of the fallout landed on City property.

Two types of ejecta were observed on February 2. The majority of the material was fine-grained silt and sand and appeared to be formation material. Some small stones were observed, but very rarely (less than 0.1% of the material). The second type was lumps, 1/4" to 1" in diameter, of bentonite clay from the completion material. This material was found only within 25 ft of the well, predominantly within 10 ft. Material this close to the well appeared to be well-washed by water fall from the plume, but bentonite was always under the other material and often firmly stuck to pipes and to the side of the separator. This may be interpreted to mean that the bentonite came out first and at a lower velocity than the later ejecta.

The temperature of the plume was not measured; however, relatively little of the plume fell as water, indicating a large steam fraction.

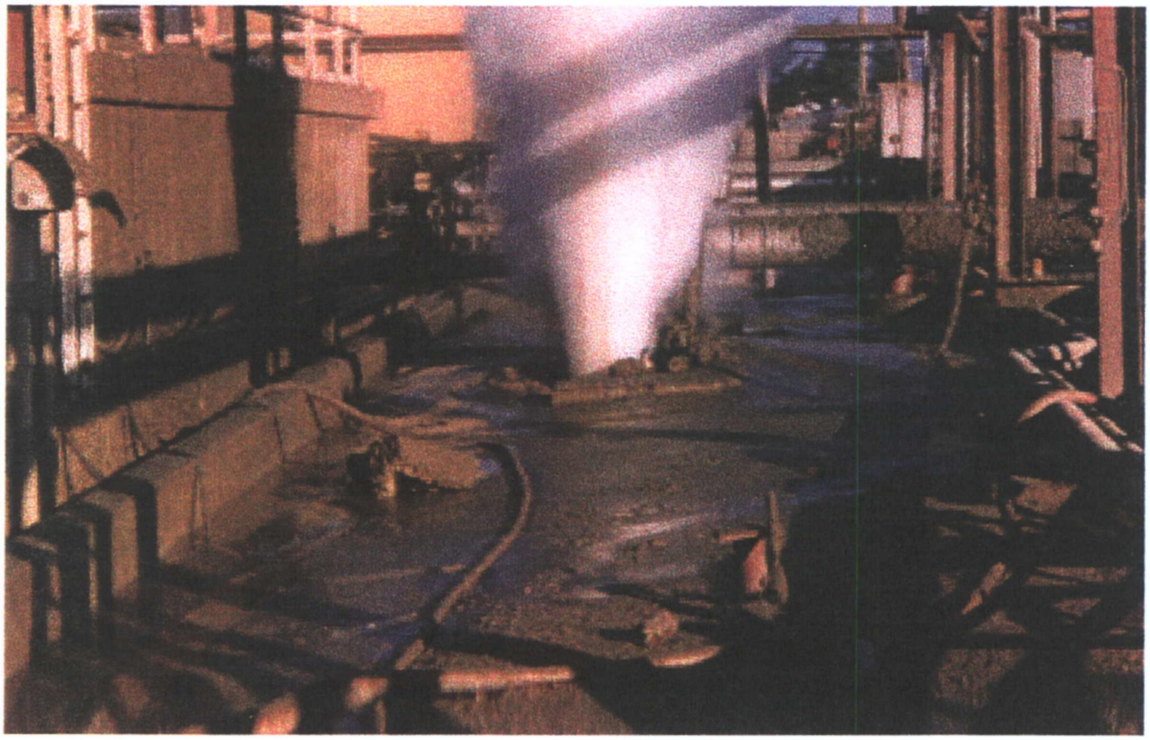
Subsurface Temperatures Temperatures measured in wells ERT-4 (25 ft W of EW-5) and ERT-5 (50 ft N of EW-5) showed deep-aquifer temperatures of 138–140°C, slightly above the boiling point (~135°C) at that depth due to the applied hydrostatic head before the eruption. Temperatures of 140°C correspond to steam pressure of 38 psig. The approximate lithology is shown in Figure 2. Temperature logs before, during, and after the eruption are shown in Figure 3. The above-boiling-point temperatures were not unusual for steam-injection operations; this is a common degree of overpressure.

Logs of wells ERT-1 and -2, in particular, show that the boiling-point temperatures had encroached into the aquitard up to depths of 110 ft, approximately 10 ft into the aquitard material. “Huff and puff” operation of a steaming process is intended to ratchet the steam zone into aquitard materials by slightly overpressuring them, then releasing the pressure, which causes any portion of the aquitard above the new boiling point to be disrupted by steam generation. This mechanism was apparently active in the progress of the steam zone upward into the aquitard, and can readily be imagined to have contributed to liquefying bentonite in the well completion and potentially removing it by stoping processes, causing the bentonite to fall out of the conductor casing. Settling and mobilization of fines during previous steaming may have created some void space below the bentonite in the filter pack (around the screen), starting the stoping process.

MW-34 Mud Venting In January, well MW-34 (NE of the office building) vented bentonite mud and was successfully quenched by applying water from the quench system (details on this event are incomplete). This well is completed in the deep aquifer and uses construction methods similar to EW-5. The 107 ft conductor casing in well MW 34 is 10” diameter. According to Billy Milam, mud erupted from both the top of the well (the yellow “can” surrounding the 4" casing) and from under the concrete pad. Mud was thrown high enough to hit the top of the nearby stairs. No steam escaped.

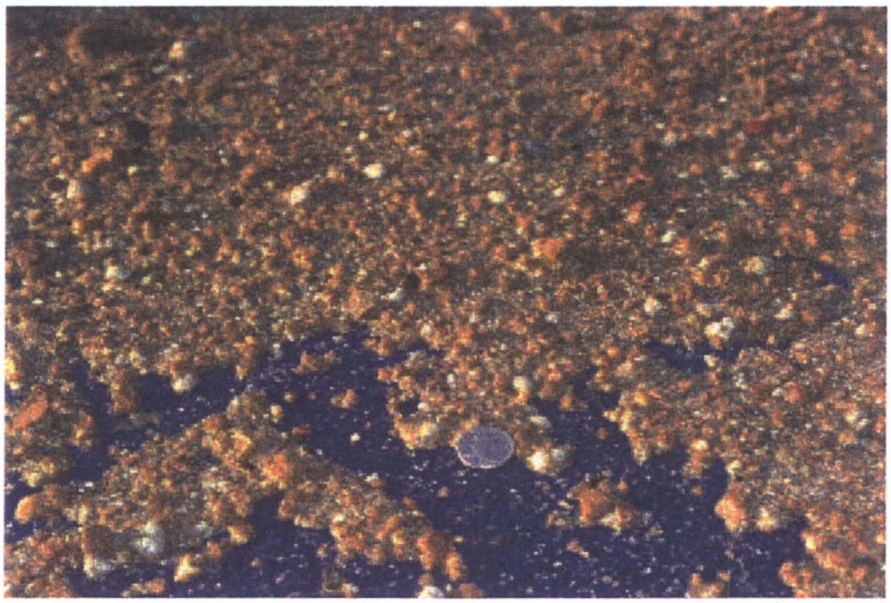
The MW 34 mud event appears similar to the EW-5 eruption. Analysis of why it proceeded slowly and responded to normal quenching procedures will be valuable. This well had been actively cooled using LLNL's circulating cooling system until mid December, when the cooling systems were removed from all 4 pre-existing PVC wells (MW 34 and 44 in the deep aquifer, MW 36 and 41 in the intermediate aquifer).

Photos



Geyser during eruption (from the west). A dislodged, triangular chunk of concrete from the well cap lies at center left. Streaks of brown silt may be seen in the plume. Bentonite that appeared to have erupted by an early, much less vigorous process is stuck to the separator wall at the left.

Quenched well on February 2, from the foundation of the separator (north of the well). The 2" pipe from left was used in attempting to quench the well. The concrete cap had cracked behind the upright well casing. Mud is under the concrete, indicating that the cap had been raised while mud escaped and implying that the triangular chunk broke out after some eruption had occurred.



Ejected mud and silt. Lower photo shows detail from the back of the police sedan. Chunks are almost all bentonite; quarter is for scale. Well EW-5 can be seen in the background between the vehicles. Silt depth in front of these vehicles was about 1 inch.

Analysis and Physical Causes

Open conduits to the steam zone have long been a concern in the application of steam remediation. The first large-scale geyser occurred in the clean-site test conducted in 1991. That geyser was successfully controlled by application of cold water. Since then, DUS applications, including Visalia, have incorporated dedicated quench ports on all wells. The EW-5 eruption occurred via a conduit that was not anticipated and not addressable by the existing quench mechanisms.

The source of this eruption was the 16" conductor. The conductor casing was filled with bentonite, which apparently became liquefied and lost strength, allowing bubbles of steam to rise through it, removing the bentonite. This assessment is based on the mud eruptions from MW-34 and the apparently low-energy mud splattering around EW-5; there are currently no eyewitness accounts to verify that mud came out slowly at the beginning of the event. Personnel from the Visalia City Corporation Yard should be consulted conerning supplying more information about this inference.

Once the majority of the bentonite mud was removed, the simple lifting force of the 38-psi aquifer steam pressure was sufficient to lift the concrete pad over the well. Approximately 5000 lb of lift could be generated (the pad occupied 150 square inches, including the area removed by the 8" casing). The concrete pad originally surrounded the intact 8" well casing, but the pad fractured and a triangular chunk was found about 8 ft away. This failure allowed the steam direct access to the surface. The initial eruption would have almost certainly been water lifted by steam, but with the insulation of the steel conductor casing, the steam eruption would then continue unabated. It is likely that the initial lifting of the concrete sheared off the quench valve, which was welded into the 8" casing about 18" from ground surface. The valve was found in the mud about 3 ft to the west of well EW-5, without any of the traces of sandblasting that other metal in the wellhead evidenced.

Thermal analysis of changes in aquifer temperature indicates that the deep aquifer yielded steam throughout the area monitored by temperature wells. The temperature dropped quickly to just below the applied boiling point, which would be expected as the applied pressure on the aquifer was reduced by communication with the geyser. After the geyser stopped, overall temperatures in the aquifer had been reduced by an average of 11.9°C. This value can be considered together with the heat capacities of soil and water to estimate that approximately 1.9 billion BTUs were released (attached calculations). If this thermal energy were used to generate steam at a constant 135°C, an average of about 174,000 lb/hr (average) of steam would be produced over the 12 hours of eruption time. This calculation is preliminary and depends on several major assumptions, including the size of the communicating steam zone; it does not take into account other fluid movement or the pressure-volume (PV) work done on expansion.

The magnitude of the steam released indicates why the well could not be quenched with water applied from the top.

Temperature logs indicate that the eruption continued isothermally, but with some gradual increase in applied aquifer pressure indicating a smaller steam zone and encroaching formation water. At some point there would eventually have been no energy left to produce steam, but the eruption stopped much more suddenly than simple energy loss could indicate. Apparently the gravel and sand suspended in the eruption column became too heavy, and as the eruption slowed the gravel fell back into the well. This material bridged against itself and the two concentric pipes, reducing the flow velocity dramatically. The accompanying pressure increase below that point would have instantly quenched the steam zones, which were below the boiling-point temperature at the natural aquifer pressure. Quench water added through the 8" well casing at this point further cooled the system and ensured no further eruptions would occur.

Quench water added to well S-14 provided a very small amount of overall cooling compared to the heat release through the geyser (see calculations), but resulted in a significant decrease in the 135-ft temperatures in ERT-1. This creation of a cold spot in the aquifer may have changed the aquifer pressure gradients enough to slow the eruption rate, allow the bridge to form, and stop the eruption. Further analysis of this effect is warranted, because it may be a very viable option for reducing the effect of similar events where there is no opportunity to directly cool the failure location.

Temperature logs indicate that the entire aquifer was producing steam, and that most of the heat loss occurred in the aquifer from 115 to 135 ft. The aquitard from 107 to 115 ft showed little permanent temperature change in the monitoring wells, which may have experienced different flow than the region of well EW-5. Based on this data, however, it appears that steam flowed through the aquifer horizontally to the EW-5 well, where vertical flow eroded the aquitard material as it passed up and into the casing at 107 ft. The soil removed by the eruption appears to have been consistent in mineralogy and chemistry to that originally logged just below the conductor casing in the drilling of this well. Electric casing logs run after the eruption showed potential voids from about 100 ft to 130 ft, the top of the screened zone. This area accepted approximately 24 cubic yards of grout after the casing was perforated.

Findings

The root cause of this failure was the bentonite grout within the deep conductor casing. Bentonite cannot be relied upon to seal steam wells.

The concrete cap on the well was not heavy enough to contain the pressure from the steam zone once the bentonite liquefied. The cap was unreinforced and broke into several pieces. The small size and fragile nature of this cap may be the reason that this event turned into a large eruption, in contrast to the MW-34 mud eruption, which was easily quenched by existing procedures.

The quench system might have been capable of calming the well in the initial (unseen) stages of the failure, but the quench port was removed by the concrete cap movement, or venting steam and sand. It clearly would have provided inadequate cooling capacity when the geyser was operating fully, at which time a cooling capacity capable of condensing a significant fraction of several hundred thousand pounds of steam per hour would have been required. Oil-field practices should be followed for further deep injections in which this amount of stored energy is available. Quench water needed to have been applied at the aquifer level to be effective.

A method for verifying the integrity of wells in deep steam-injection zones should be developed and employed.

Wells MW-34, MW-44, and any other bentonite-grouted wells in the deep aquifer should be destroyed by drilling out the bentonite and grouting with high-temperature cement grout.

The factors causing the eruption to stop include the loss of formation energy, addition of quench water to S-14D, and formation of a bridge in the bottom of the conductor casing. The relative contributions of these factors are not yet known and warrant further study.

Edison personnel followed all applicable safety procedures and are to be commended that no one was injured during this event.

Figures

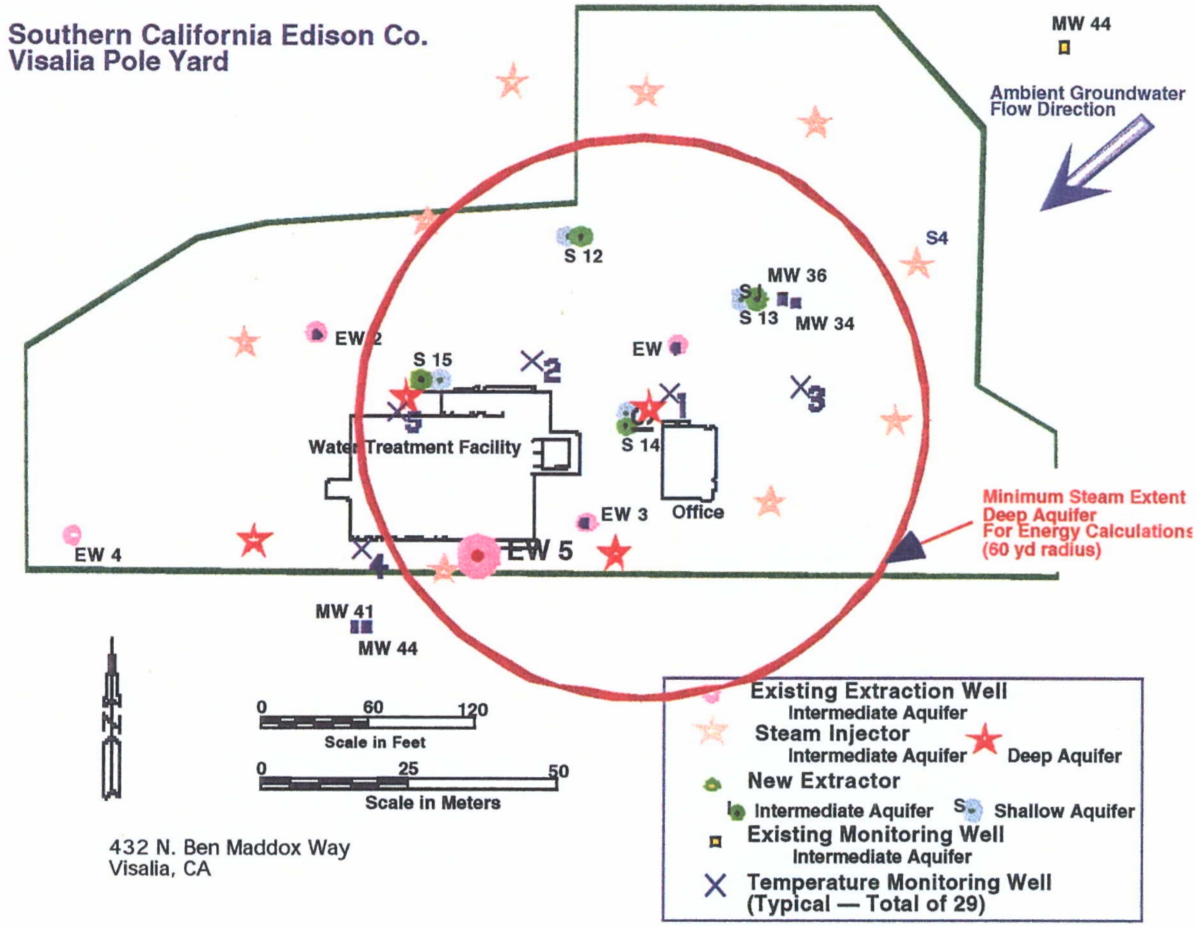


Figure 1. Map of the monitoring and operational wells used for deep-aquifer treatment at Visalia.

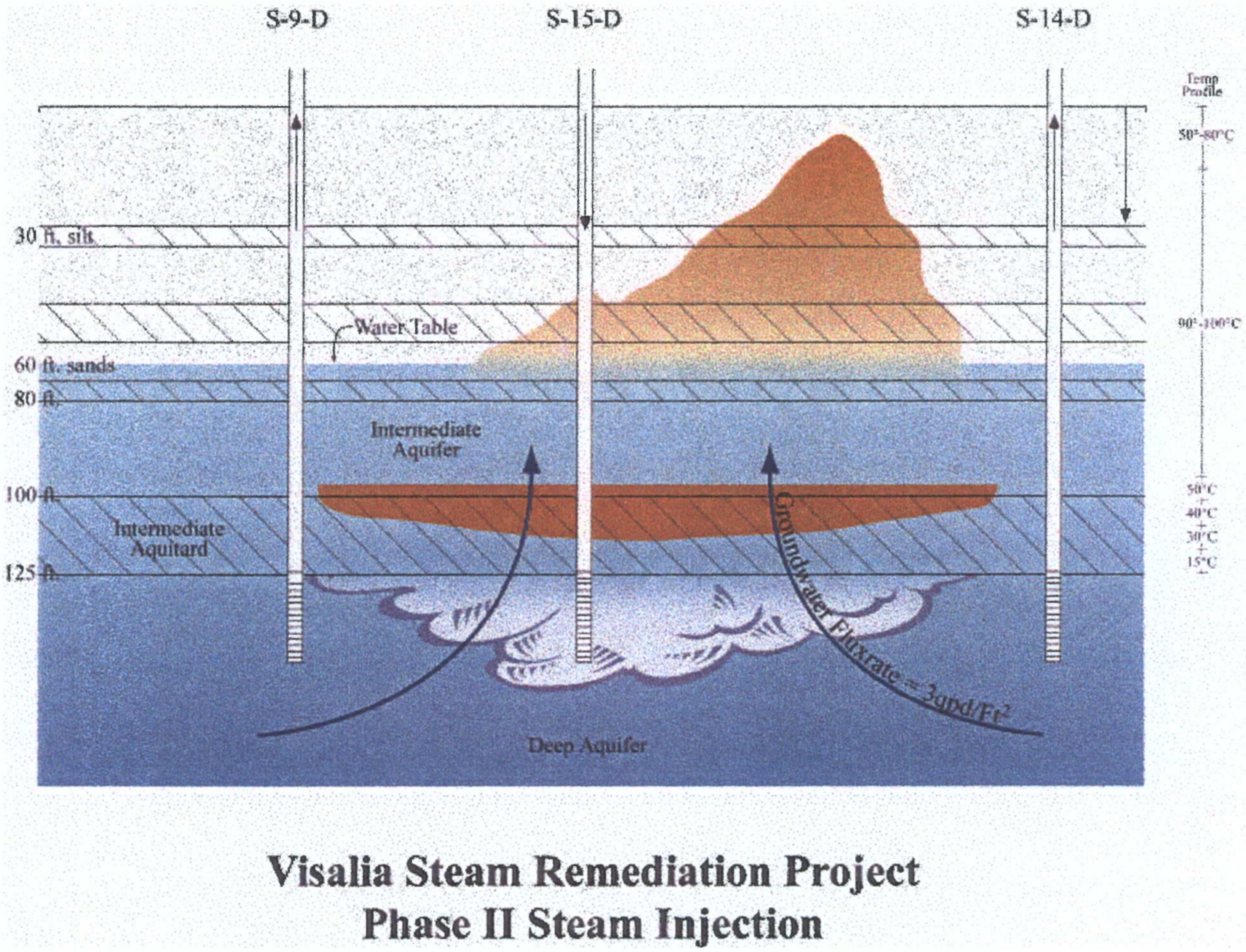
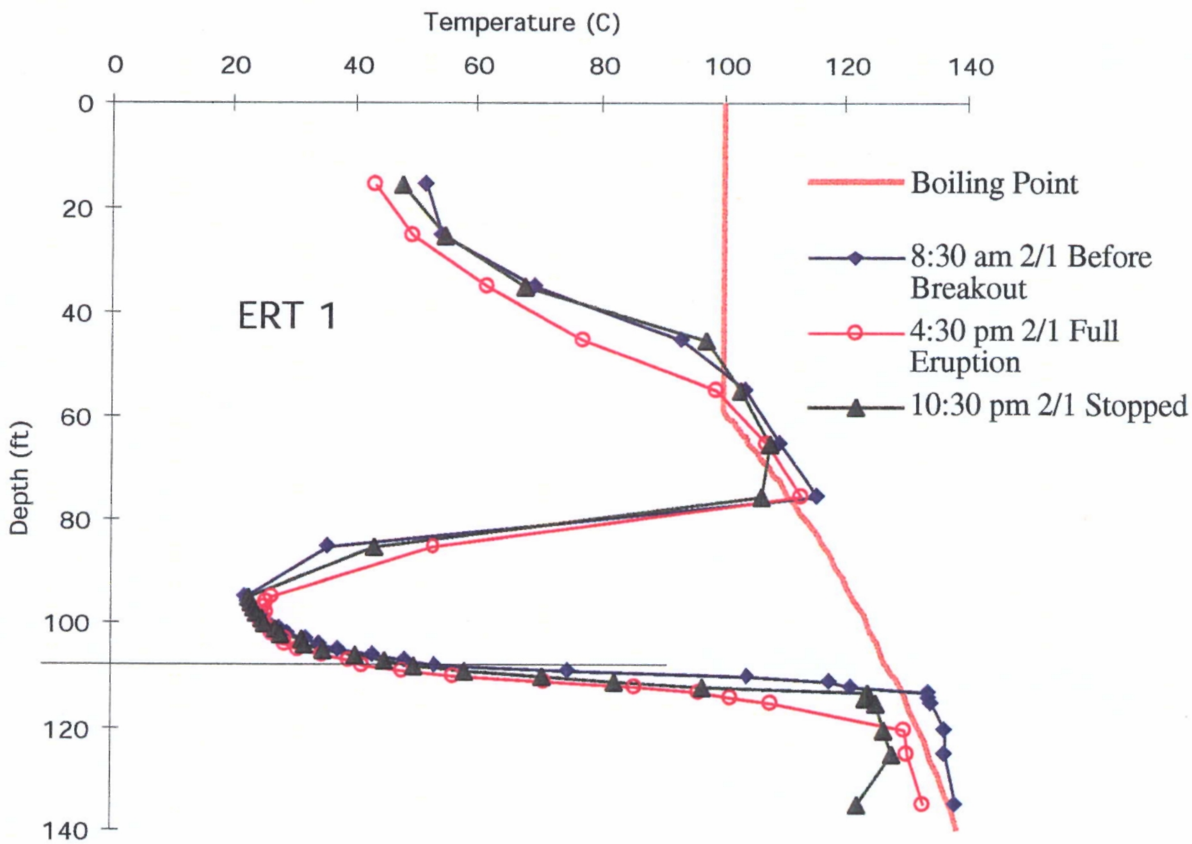
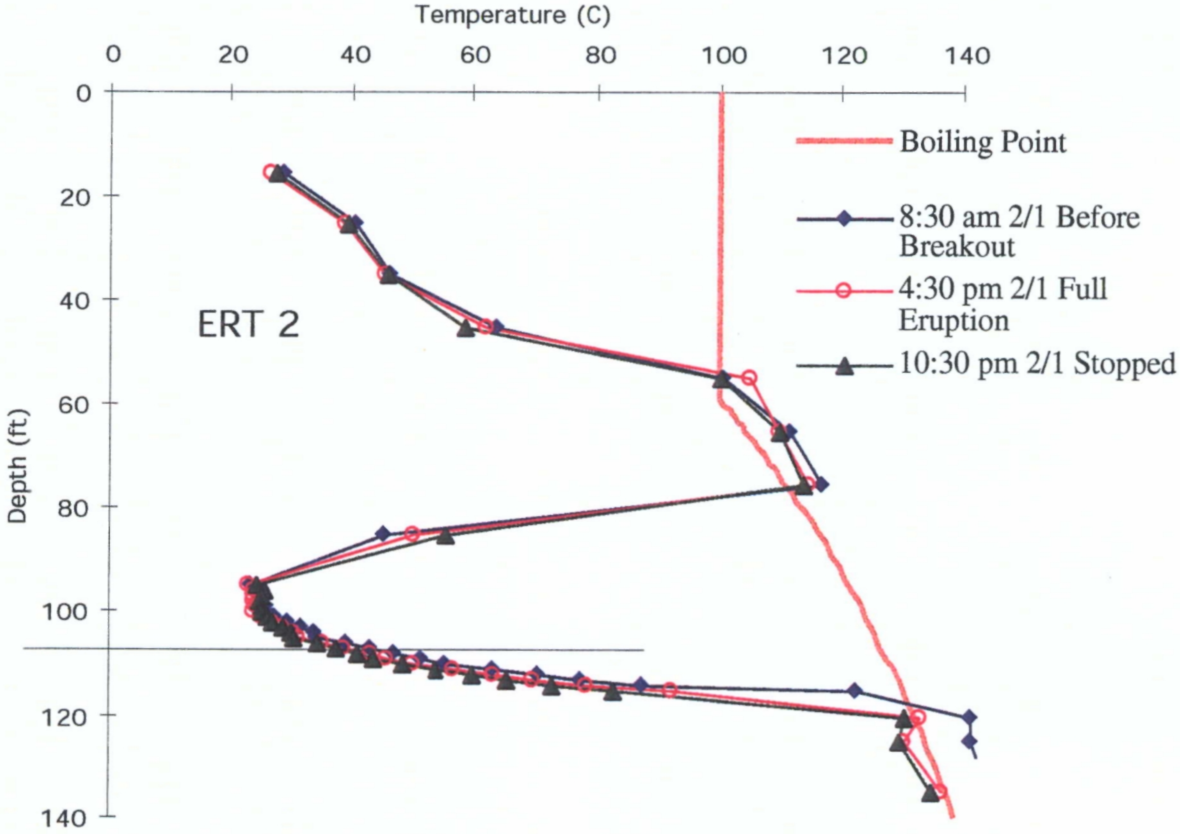
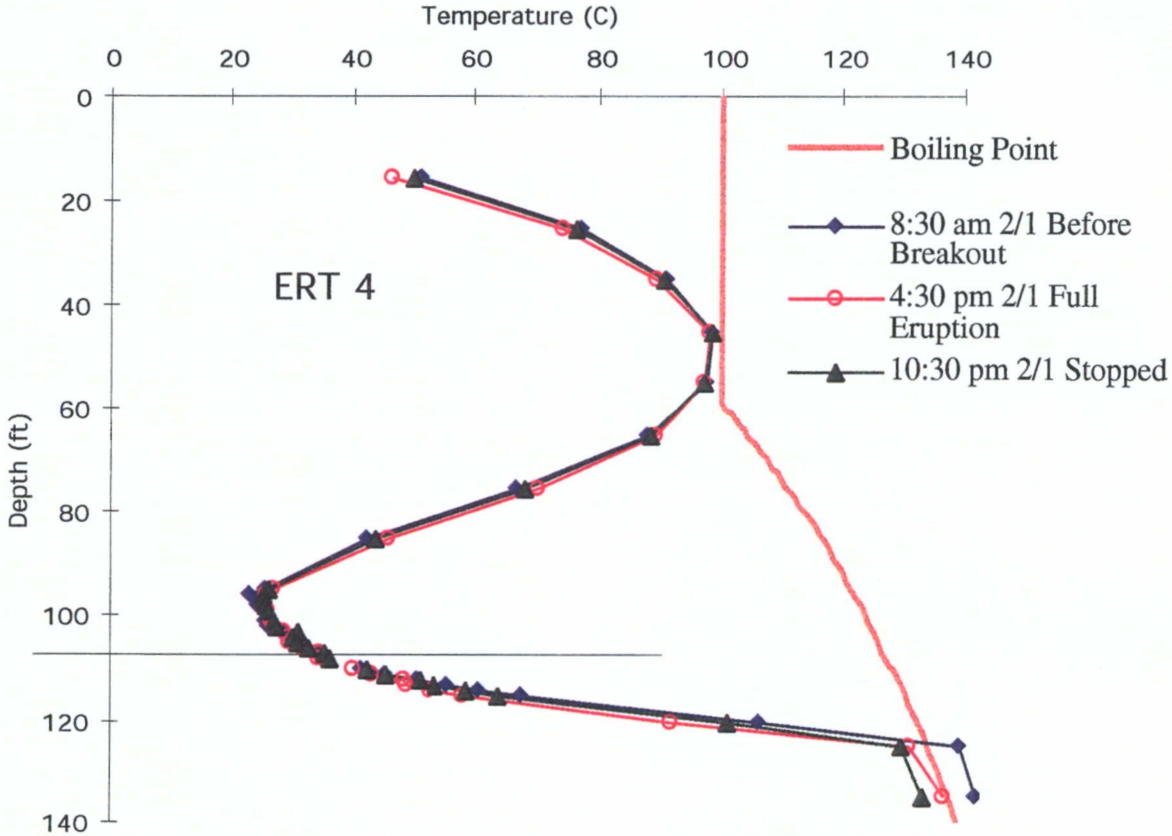


Figure 2. Edison conceptual drawing of the heating of the deep aquitard by injection of steam into the deep aquifer.


Temperature (C)
0
20
40
60
80
100
120
140
0
20
40
60
80
100
120
140
Depth (ft)
ERT 1
Boiling Point
8:30 am 2/1 Before Breakout
4:30 pm 2/1 Full Eruption
10:30 pm 2/1 Stopped



Temperature (C)
0
20
40
60
80
100
120
140
Depth (ft)
ERT 2
Boiling Point
8:30 am 2/1 Before Breakout
4:30 pm 2/1 Full Eruption
10:30 pm 2/1 Stopped



Temperature (C)
0
20
40
60
80
100
120
140
Depth (ft)
0
20
40
60
80
100
120
140
ERT 4
Boiling Point
8:30 am 2/1 Before Breakout
4:30 pm 2/1 Full Eruption
10:30 pm 2/1 Stopped

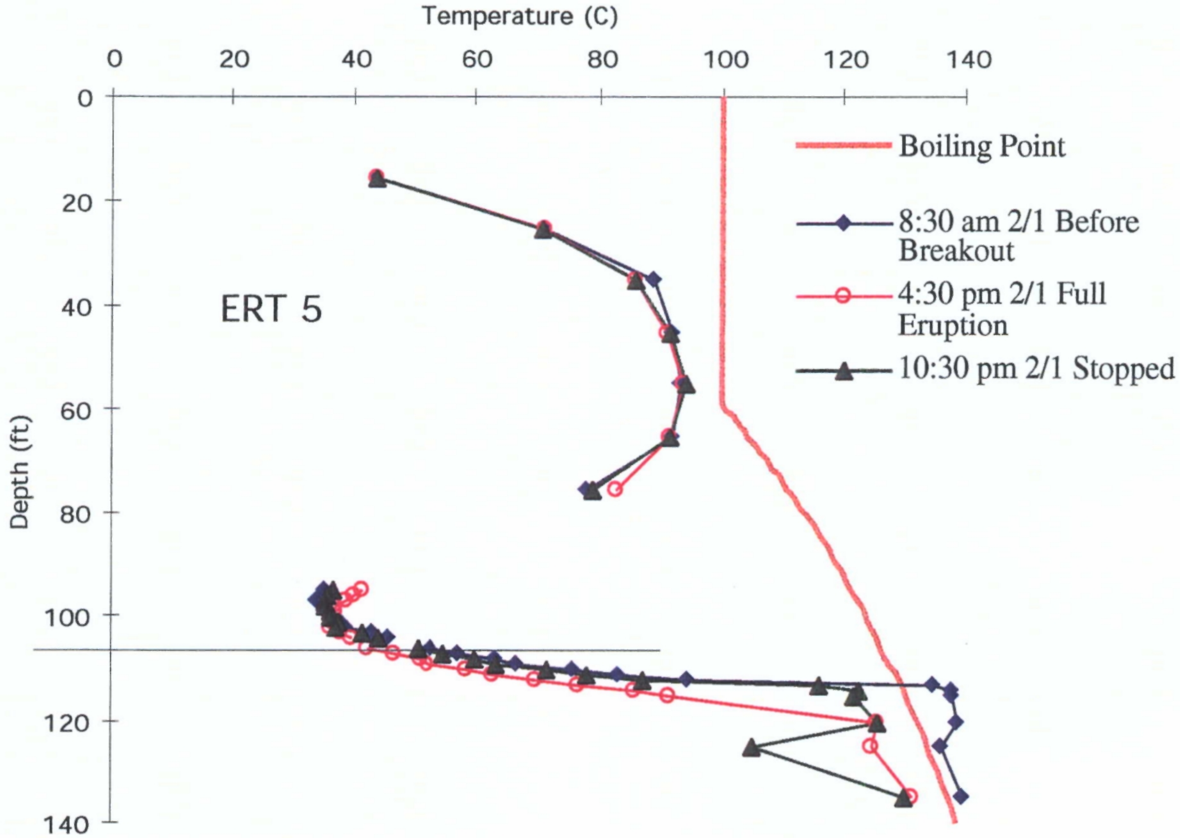


Figure 3. Temperature profiles as a function of depth for the four closest monitoring wells before, during, and after the eruption on February 1, 1999. The horizontal line is approximately at the depth of the conductor casing. The boiling point line is calculated from water levels in the two aquifers (hence the small offset at about 110 ft; the lower aquifer has a head about two feet taller than the upper). This calculation may not precisely reflect the natural boiling point in all locations—e.g., ERT-2 appears to be slightly above the calculated boiling point in the upper regions, for which there is no apparent lithologic or hydrologic basis. Breaks in the curves (e.g., at 85 ft in ERT-5) indicate failed thermocouples. The notable offset in the full-eruption temperatures in ERT-1 are probably due to the presence of water in the temperature monitoring tube, slightly supported by a steam bubble near the bottom. When temperatures collapsed, the bubble collapsed and allowed water in the tube to drop lower. This caused a temporary offset in the observed temperatures. This log indicates that the water dropped several feet. The formation temperatures quickly re-equilibrate the water in the tube, which is 2" in diameter and filled with sand.

Analyses

1) Assess average temperature change in reservoir

Average decline, all five wells (ERT 1–5):
135–115', 11.9°C
8:30 a.m. to 10:30 p.m.

Basic conversion data:

soil heat cap	0.2	cal/g °C
water heat cap	1.0	cal/g °C
cc's per cubic yd	764,555	cc/yd

2) Determine how much heat loss the temperature represents

A) How large is the volume (deep-aquifer volume contributing to geyser)?

Thickness	7 yd
Radius (S-14D)	60 yd
Volume	79,166 yd^3
	60.5×10^9 cc

B) How much soil and water is in that volume, and how much heat did it lose?

	Total weight	cal @ avg decline
Water @ 20% soil porosity	12.1×10^9 g	143.7×10^9
Soil @ 3 g/cc density	145.3×10^9 g	344.9×10^9
Total		488.6×10^9 cal

C) How much of the cooling was due to the cold water into S-14D?

gallons/minute	100
gallons/hr	6000
grams/hr	22.7×10^6
hours	4
calories, 20° to 135°C	-2.6×10^9 cal

D) Total heat change in aquifer, less the effect of the cooling water

total minus cold water 486.0×10^9 calories
$= 1.9 \times 10^9$ BTU
= 568 MW
= 761,600 HP

E) Average the effects over 12 hrs of eruption: 47 MW/hr = 63,464 HP/hr

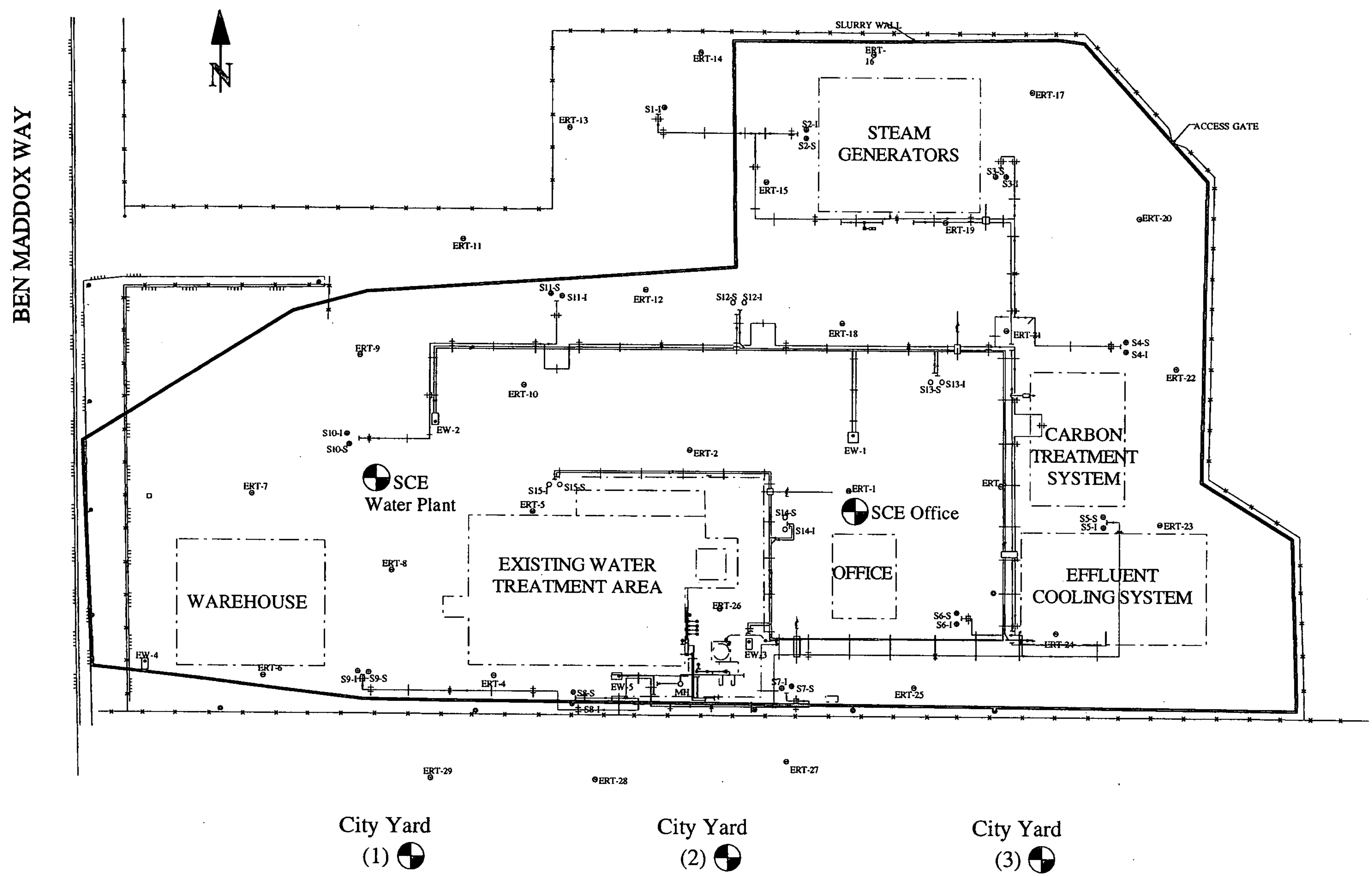
3) Calculate the amount of material, assuming steam was being generated at about 135°C

927 BTU/lbm enthalpy to generate steam

A) Total steam generated at 135°C 2,092,091 lb
261,511 gal

B) Average steam generated 174,341 lb/hr
363 gal/min

APPENDIX B



LEGEND

AIR MONITORING LOCATION

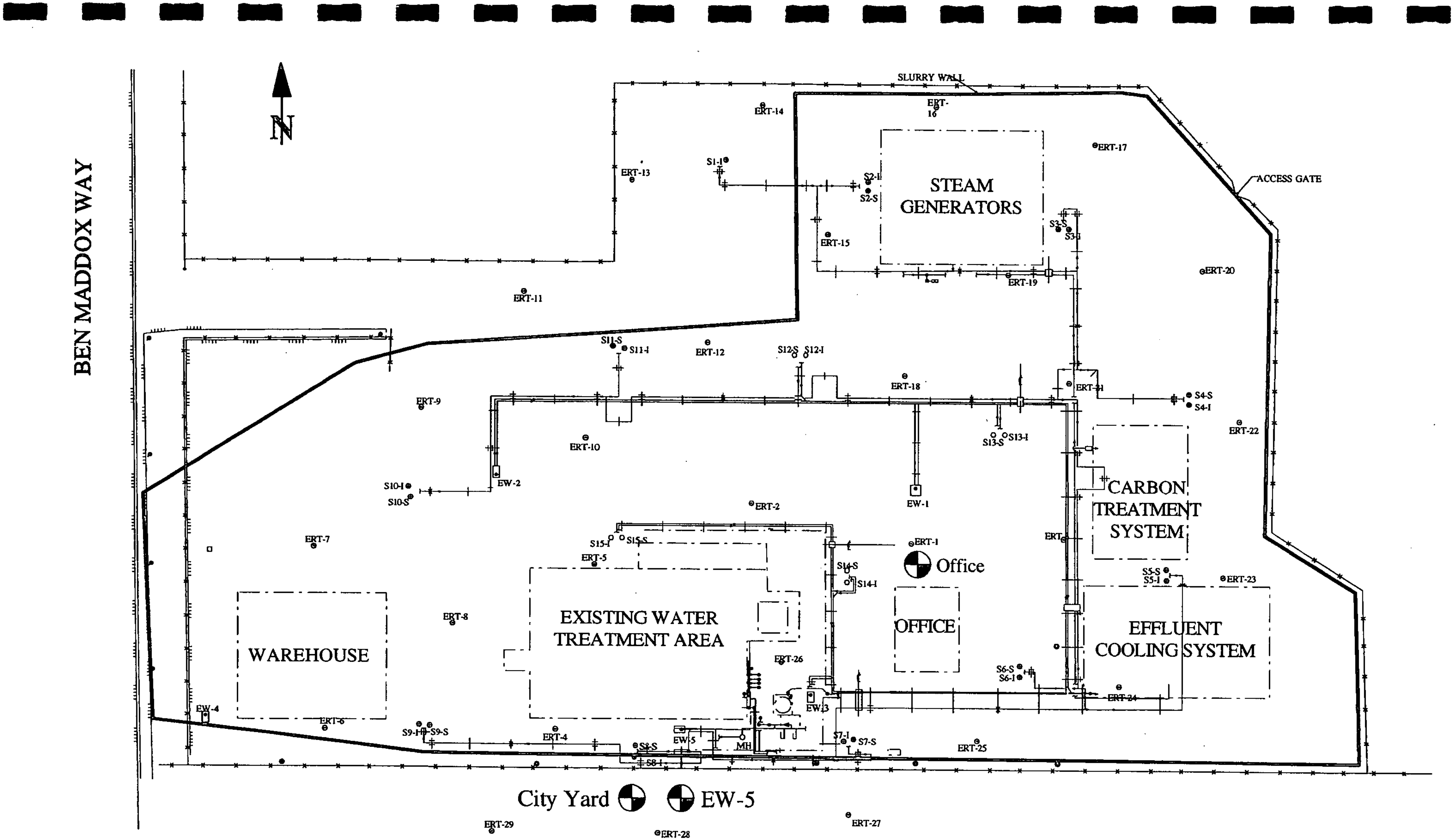
AIR MONITORING LOCATIONS
EW-5 EVENT
VISALIA POLE YARD

02/04/99 14:30 FAX 2097352361 SCE ☑02

Visalia Steam Remediation Project
EW-5 Steam Blowout - Air Sampling
VOC Measurements

	SCE Office Building	SCE Water Plant	City Yard - Location 1	City Yard - Location 2	City Yard - Location 3
Date: 2/1/99	VOC - (ppm)	VOC - (ppm)	VOC - (ppm)	VOC - (ppm)	VOC - (ppm)
Time: 1030 hrs	0.1	0.1	0	0.1	0.1
Time: 1050 hrs	0	0.1	0.1	0.1	0.1
Time: 1110 hrs	0	0.1	0	0	0.1
Time: 1130 hrs	0.1	0	0.1	0.1	0.1
Time: 1150 hrs	0	0.1	0.1	0.1	0
Time: 1210 hrs	0.1	0.1	0	0	0
Time: 1230 hrs	0.1	0	0	0.1	0.1
Time: 1250 hrs	0	0.1	0	0.1	0
Time: 1310 hrs	0.1	0.1	0	0	0.1
Time: 1330 hrs	0.1	0	0	0.1	0
Time: 1350 hrs	0.1	0.1	0	0	0.1
Time: 1630 hrs	0	0.1	0.1	0.1	0.1
Time: 1730 hrs	0	0	0	0.1	0
Time: 1830 hrs	0	0.1	0	0.1	0.1

APPENDIX C



SOIL SAMPLE LOCATIONS
EW-5 EVENT
VISALIA POLE YARD

LEGEND

SOIL SAMPLING LOCATION

Calscience Environmental Laboratories, Inc.

February 02, 1999

Craig Eaker
Southern California Edison
2244 Walnut Grove Avenue
Rosemead, CA 91770

Subject: **Calscience Work Order Number: 99-02-0025**
Client Reference: SCE VPY Steam Remediation

Dear Client:

Enclosed is an analytical report for the above-referenced project. The samples included in this report were received 02/01/99 and analyzed in accordance with the attached chain-of-custody.

The results in this analytical report are limited to the samples tested, and any reproduction of this report must be made in its entirety.

If you have any questions regarding this report, require sampling supplies or field services, or information on our analytical services, please feel free to call me at (714) 895-5494.

Sincerely,

Calscience Environmental Laboratories, Inc.
William H. Christensen
Quality Assurance Manager

William H. Christensen
Quality Assurance Manager

Calscience Environmental Laboratories, Inc.

ANALYTICAL REPORT

Southern California Edison	Date Sampled: 02/01/99
2244 Walnut Grove Avenue	Date Received: 02/01/99
Rosemead, CA 91770	Date Extracted: 02/01/99
	Date Analyzed: 02/01/99
	Work Order No.: 99-02-0025
Attn: Craig Eaker	Method: EPA 8270C
RE: SCE VPY Steam Remediation	Page 1 of 3

All concentrations are reported in mg/kg (ppm).

Sample Number: City Yard

Analyte	Concentration	Reporting Limit
Naphthalene	ND	1.0
2-Methylnaphthalene	ND	1.0
1-Methylnaphthalene	ND	1.0
Acenaphthylene	ND	1.0
Acenaphthene	ND	1.0
Fluorene	1.5	1.0
Pentachlorophenol	ND	5.0
Phenanthrene	22.6	1.0
Anthracene	2.0	1.0
Fluoranthene	10.8	1.0
Pyrene	8.9	1.0
Benzo (a) Anthracene	1.7	1.0
Chrysene	2.1	1.0
Benzo (b) Fluoranthene	ND	1.0
Benzo (k) Fluoranthene	ND	1.0
Benzo (a) Pyrene	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	1.0
Dibenzo (a,h) Anthracene	ND	1.0
Benzo (g,h,i) Perylene	ND	1.0

Calscience Environmental Laboratories, Inc.

ANALYTICAL REPORT

Southern California Edison
2244 Walnut Grove Avenue
Rosemead, CA 91770

Attn: Craig Eaker
RE: SCE VPY Steam Remediation

Date Sampled:	02/01/99
Date Received:	02/01/99
Date Extracted:	02/01/99
Date Analyzed:	02/01/99
Work Order No.:	99-02-0025
Method:	EPA 8270C
Page 2 of 3	

All concentrations are reported in mg/kg (ppm).

Analyte	Concentration	Reporting Limit
Sample Number: Office		
Naphthalene	ND	1.0
2-Methylnaphthalene	ND	1.0
1-Methylnaphthalene	ND	1.0
Acenaphthylene	ND	1.0
Acenaphthene	ND	1.0
Fluorene	ND	1.0
Pentachlorophenol	ND	5.0
Phenanthrene	1.3	1.0
Anthracene	ND	1.0
Fluoranthene	5.1	1.0
Pyrene	4.8	1.0
Benzo (a) Anthracene	1.7	1.0
Chrysene	2.7	1.0
Benzo (b) Fluoranthene	ND	1.0
Benzo (k) Fluoranthene	0.4	1.0
Benzo (a) Pyrene	0.2	1.0
Indeno (1,2,3-cd) Pyrene	ND	1.0
Dibenzo (a,h) Anthracene	ND	1.0
Benzo (g,h,i) Perylene	ND	1.0

Calscience Environmental Laboratories, Inc.

ANALYTICAL REPORT

Southern California Edison	Date Sampled: 02/01/99
2244 Walnut Grove Avenue	Date Received: 02/01/99
Rosemead, CA 91770	Date Extracted: 02/01/99
	Date Analyzed: 02/01/99
	Work Order No.: 99-02-0025
Attn: Craig Eaker	Method: EPA 8270C
RE: SCE VPY Steam Remediation	Page 3 of 3

All concentrations are reported in mg/kg (ppm).

Analyte	Concentration	Reporting Limit
Sample Number: Method Blank		
Naphthalene	ND	1.0
2-Methylnaphthalene	ND	1.0
1-Methylnaphthalene	ND	1.0
Acenaphthylene	ND	1.0
Acenaphthene	ND	1.0
Fluorene	ND	1.0
Pentachlorophenol	ND	5.0
Phenanthrene	ND	1.0
Anthracene	ND	1.0
Fluoranthene	ND	1.0
Pyrene	ND	1.0
Benzo (a) Anthracene	ND	1.0
Chrysene	ND	1.0
Benzo (b) Fluoranthene	ND	1.0
Benzo (k) Fluoranthene	ND	1.0
Benzo (a) Pyrene	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	1.0
Dibenzo (a,h) Anthracene	ND	1.0
Benzo (g,h,i) Perylene	ND	1.0

ND denotes not detected at indicated reportable limit.

Each sample was received by CEL chilled, intact, and with chain-of-custody attached.

Calscience Environmental Laboratories, Inc.

QUALITY ASSURANCE SUMMARY
Method EPA 8270C

Southern California Edison
Page 1 of 1

Work Order No.: 99-01-0025
Date Analyzed: 02/02/99

Matrix Spike/Matrix Spike Duplicate
Sample Spiked: 99-01-0720-11

Analyte	MS%REC	MSD%REC	Control Limits	%RPD	Control Limits
Phenol	102	101	20 - 120	1	0 - 42
2-Chlorophenol	97	96	23 - 134	1	0 - 40
1,4-Dichlorobenzene	97	95	20 - 124	2	0 - 28
N-Nitroso-di-n-propylamine	96	94	D - 230	2	0 - 38
1,2,4-Trichlorobenzene	97	95	44 - 142	2	0 - 28
Acenaphthene	107	105	47 - 145	2	0 - 31
2,4-Dinitrotoluene	91	88	39 - 139	3	0 - 38

Surrogate Recoveries (in %)

Sample Number	S1	S2	S3	S4	S5	S6
City Yard	79	79	74	85	75	85
Office	91	90	83	96	87	97
Method Blank	85	84	81	89	83	88

Surrogate Compound	Soil %REC Acceptable Limits
S1 > 2-Fluorophenol	25 - 121
S2 > Phenol-d_6	24 - 113
S3 > Nitrobenzene-d_5	23 - 120
S4 > 2-Fluorobiphenyl	30 - 115
S5 > 2,4,6-Tribromophenol	19 - 122
S6 > p-Terphenyl-d14	18 - 137

7440 Lincoln Way, Garden Grove, CA 92841-1432 • TEL: (714) 895-5494 • FAX: (714) 894-7501

SCE - ROSEMEAD, CA
ENVIRONMENTAL AFFAIRS
G01, ROOM 405

CHAIN OF CUSTODY RECORD

Date 2-1-99

Page 1 of 1

FEB-03-1999 08:49 CALSCIENCE 714 894 7501 P.07/12

LABORATORY CLIENT:	Southern California Edison Co.
ADDRESS:	2244 Walnut Grove Avenue
CITY	Rosemead, STATE CA ZIP 91770
TEL: 626 / 302-8531	FAX: 626 / 302-9730 E-MAIL: @sce.com
SCE PROJECT NAME / NUMBER:	Poleyard
PROJECT CONTACT:	C EAKER
SAMPLER(S): (SIGNATURE)	[signature]
P.O. NO.:	
QUOTE NO.:	
LAB USE ONLY	0 2 0 0 2 5

TURNAROUND TIME ☐ SAME DAY ☐ 24 HR ☐ 48 HR ☐ 72 HRS ☐ 5 DAYS ☐ 10 DAYS

SPECIAL INSTRUCTIONS

CALL C EAKER AT 626-302-8531 OR 559-735-2360

REQUESTED ANALYSES: EPA 8280; EPA 525.2 (SCE LIST); EPA 8270C (SCE LIST); TPH (d). RL = 0.05 ppm; TPH (g) (d) (o)___; BTEX / MTBE (8021B); HALOCARBONS (8021B); VOCs (8260B); SVOCs (8270C); PEST / PCBs (8081A); CAC. T22 METALS (6010A); ICP / MS METALS (6020); PNAs (8310); VOCs (TO-14)

LAB USE ONLY	SAMPLE ID	LOCATION/DESCRIPTION	SAMPLING DATE	SAMPLING TIME	MATRIX	NO. OF CONT.
		City Yard	2-1	1445	Sand	1
		Johns Car At Office Door	2-1	1500	Sand	1

Relinquished by: (Signature) [signature]	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received for Laboratory by: (Signature) [signature]	Date: 2/1/99	Time: 19:50

9/27/97 Revision

All turnaround times are based on working hours of 8:30 a.m. - 5:30 p.m. M - F. Unless otherwise requested, all samples will be disposed of 30 days after receipt.

DISTRIBUTION: White with final report, Yellow to File, Pink to SCE

Calscience Environmental Laboratories, Inc.

February 02, 1999

Craig Eaker
Southern California Edison
2244 Walnut Grove Avenue
Rosemead, CA 91770

Subject: **Calscience Work Order Number: 99-02-0029**
Client Reference: SCE VPY Steam Remediation

Dear Client:

Enclosed is an analytical report for the above-referenced project. The samples included in this report were received 02/02/99 and analyzed in accordance with the attached chain-of-custody.

The results in this analytical report are limited to the samples tested, and any reproduction of this report must be made in its entirety.

If you have any questions regarding this report, require sampling supplies or field services, or information on our analytical services, please feel free to call me at (714) 895-5494.

Sincerely,

Calscience Environmental
Laboratories, Inc.
William H. Christensen
Quality Assurance Manager

William H. Christensen
Quality Assurance Manager

Calscience Environmental Laboratories, Inc.

ANALYTICAL REPORT

Southern California Edison	Date Sampled: 02/01/99
2244 Walnut Grove Avenue	Date Received: 02/02/99
Rosemead, CA 91770	Date Extracted: 02/02/99
	Date Analyzed: 02/02/99
	Work Order No.: 99-02-0029
Attn: Craig Eaker	Method: EPA 8270C
RE: SCE VPY Steam Remediation	Page 1 of 2

All concentrations are reported in mg/kg (ppm).

Sample Number: EW-5

Analyte	Concentration	Reporting Limit
Naphthalene	ND	1.0
2-Methylnaphthalene	ND	1.0
1-Methylnaphthalene	ND	1.0
Acenaphthylene	ND	1.0
Acenaphthene	ND	1.0
Fluorene	ND	1.0
Pentachlorophenol	ND	5.0
Phenanthrene	1.0	1.0
Anthracene	ND	1.0
Fluoranthene	4.2	1.0
Pyrene	4.4	1.0
Benzo (a) Anthracene	1.4	1.0
Chrysene	1.8	1.0
Benzo (b) Fluoranthene	ND	1.0
Benzo (k) Fluoranthene	ND	1.0
Benzo (a) Pyrene	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	1.0
Dibenzo (a,h) Anthracene	ND	1.0
Benzo (g,h,i) Perylene	ND	1.0

Calscience Environmental Laboratories, Inc.

ANALYTICAL REPORT

Southern California Edison
2244 Walnut Grove Avenue
Rosemead, CA 91770

Attn: Craig Eaker
RE: SCE VPY Steam Remediation

Date Sampled:	02/01/99
Date Received:	02/02/99
Date Extracted:	02/01/99
Date Analyzed:	02/01/99
Work Order No.:	99-02-0029
Method:	EPA 8270C

All concentrations are reported in mg/kg (ppm).

Analyte	Concentration	Reporting Limit
Sample Number: Method Blank		
Naphthalene	ND	1.0
2-Methylnaphthalene	ND	1.0
1-Methylnaphthalene	ND	1.0
Acenaphthylene	ND	1.0
Acenaphthene	ND	1.0
Fluorene	ND	1.0
Pentachlorophenol	ND	5.0
Phenanthrene	ND	1.0
Anthracene	ND	1.0
Fluoranthene	ND	1.0
Pyrene	ND	1.0
Benzo (a) Anthracene	ND	1.0
Chrysene	ND	1.0
Benzo (b) Fluoranthene	ND	1.0
Benzo (k) Fluoranthene	ND	1.0
Benzo (a) Pyrene	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	1.0
Dibenzo (a,h) Anthracene	ND	1.0
Benzo (g,h,i) Perylene	ND	1.0

ND denotes not detected at indicated reportable limit.

Each sample was received by CEL chilled, intact, and with chain-of-custody attached.

7440 Lincoln Way, Garden Grove, CA 92841-1432 • TEL: (714) 895-5494 • FAX: (714) 894-7501

Calscience Environmental Laboratories, Inc.

QUALITY ASSURANCE SUMMARY
Method EPA 8270C

Southern California Edison
Page 1 of 1

Work Order No.: 99-02-0029
Date Analyzed: 02/02/99

Matrix Spike/Matrix Spike Duplicate

Sample Spiked: 99-01-0720-11

Analyte	MS%REC	MSD%REC	Control Limits	%RPD	Control Limits
Phenol	102	101	20 - 120	1	0 - 42
2-Chlorophenol	97	96	23 - 134	1	0 - 40
1,4-Dichlorobenzene	97	95	20 - 124	2	0 - 28
N-Nitroso-di-n-propylamine	96	94	D - 230	2	0 - 38
1,2,4-Trichlorobenzene	97	95	44 - 142	2	0 - 28
Acenaphthene	107	105	47 - 145	2	0 - 31
2,4-Dinitrotoluene	91	88	39 - 139	3	0 - 38

Surrogate Recoveries (in %)

Sample Number	S1	S2	S3	S4	S5	S6
EW-5	93	91	83	103	94	105
Method Blank	85	84	81	89	83	88

Surrogate Compound	Soil %REC Acceptable Limits
S1 > 2-Fluorophenol	25 - 121
S2 > Phenol-d_6	24 - 113
S3 > Nitrobenzene-d_5	23 - 120
S4 > 2-Fluorobiphenyl	30 - 115
S5 > 2,4,6-Tribromophenol	19 - 122
S6 > p-Terphenyl-d14	18 - 137

7440 Lincoln Way, Garden Grove, CA 92841-1432 • TEL: (714) 895-5494 • FAX: (714) 894-7501

SCE - ROSEMEAD, CA
ENVIRONMENTAL AFFAIRS
GO1, ROOM 405

CHAIN OF CUSTODY RECORD

Date 2-1-99

Page 1 of 1

LABORATORY CLIENT:	Southern California Edison Co.
ADDRESS:	2244 Walnut Grove Avenue
CITY	Rosemead,
STATE	CA
ZIP	91770
TEL:	626 / 302-
FAX:	626 / 302-9730
E-MAIL:	@sce.com
SCE PROJECT NAME / NUMBER:	POLEYARD
PROJECT CONTACT:	C. EAKER
SAMPLER(S): (SIGNATURE)	[signature]
P.O. NO.:	
QUOTE NO.:	
LAB USE ONLY	0 2 -0 0 2 9

TURNAROUND TIME ☑ SAME DAY ☐ 24 HR ☐ 48 HR ☐ 72 HRS ☐ 5 DAYS ☐ 10 DAYS

SPECIAL INSTRUCTIONS

S-15 Samples on other Form

Ev-5 Sample Call CEaker for Test

REQUESTED ANALYSES

LAB USE ONLY	SAMPLE ID	LOCATION/DESCRIPTION	SAMPLING DATE	SAMPLING TIME	MATRIX	NO. OF CONT.	EPA 8280	EPA 525.2 (SCE LIST)	EPA 8270C (SCE LIST)	TPH (d), RL = 0.05 ppm	TPH (g) (d) (o)___	BTEX / MTBE (8021B)	HALOCARBONS (8021B)	VOCs (8260B)	SVOCs (8270C)	PEST / PCBs (8081A)	CAC, T22 METALS (6010A)	ICP / MS METALS (6020)	PNAs (8310)	VOCs (TO-14)	CALL C. EAKER					
		Ev-5	2-1	1000	S	1			X												X					
		~~S-15~~	~~1-31~~	~~0900~~	~~W~~	~~2~~			X																	

DUPLICATE DELETE PG. PHONE CON C. EAKER 1100/02-02-99

Relinquished by: (Signature) [signature]	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received for Laboratory by: (Signature) [signature]	Date: 2/02/99	Time: 10:00

9/27/97 Revision

All turnaround times are based on working hours of 8:30 a.m. - 5:30 p.m. M - F. Unless otherwise requested, all samples will be disposed of 30 days after receipt.

DISTRIBUTION: White with final report, Yellow to File, Pink to SCE

APPENDIX D

Department of Toxic Substances Control

Jesse R. Huff, Director
400 P Street, 4th Floor, P.O. Box 806
Sacramento, California 95812-0806

Winston H. Hickox
Secretary for
Environmental
Protection

Gray Davis
Governor

MEMORANDUM

TO: Richard Hume

FROM: Jim Carlisle J. C. Carlisle

DATE: March 18, 1999

SUBJECT: Visalia Pole Yard

Per your request, I have reviewed the reports from the analysis of three environmental samples taken following the rupture at the Visalia pole yard.

Of the 19 semi-volatile organic target analytes, only fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(k)fluoranthene, and benzo(a)pyrene were recovered. All were detected at concentrations below EPA Region IX industrial preliminary remediation goals (PRGs). The highest concentrations in relations to the PRGs were benzo(a)anthracene, detected at about ½ its PRG at both the city yard and the office, and benzo(a)pyrene, detected at about ½ its PRG at the office. Considering these two carcinogenic PAHs additively, their combined risk would be about 10^{-6} at the office and less at the other sampling locations. These estimated risks assume long-term exposure at the concentrations found. Since the material has been removed, the actual duration would be much shorter. Thus, based on the results of this limited sampling of the affected area, the presence of low concentrations of these polycyclic aromatic hydrocarbons does not appear to constitute a threat to the short-term or long-term health of the workers at this site.

Reviewed by:

T.R. Hathaway